RECOVERY OUTLINE *for the*
RUFA RED KNOT (*Calidris canutus rufa*)

March 2019

A. INTRODUCTION

1. **Species' scientific and common names:** *Calidris canutus rufa*, rufa red knot

2. **Listing status and date:** Subspecies listed as threatened throughout its entire range; December 22, 2014 (79 FR 73705-73748)

3. **Lead Regional Office:** Region 5

4. **Lead Field Office and contact biologist:** New Jersey Field Office, Wendy Walsh

5. **Level of available information and treatment of uncertainties:** Information on red knot biology and factors affecting the conservation of this species[1] is derived from numerous surveys and studies. Ground and aerial surveys, along with tracking, mark-recapture, and modeling efforts, have yielded considerable data about wintering and migration areas; migration routes and timing; life history; regional population sizes and trends; and survival rates. However, despite numerous studies conducted to date, several critical uncertainties persist and are relevant to recovery. These are addressed in the separate document U.S. Fish and Wildlife Service Rufa Red Knot Research Priorities, 2019 to 2022. These uncertainties will affect near-term section 7 consultations and section 10 permitting activities under the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*) (ESA), and could limit the efficacy of some near-term recovery actions. As needed, such uncertainties will be made explicit in terms of assumptions underlying project-specific red knot conservation efforts.

B. RECOVERY STATUS ASSESSMENT

1. **Biological assessment:** The rufa red knot is a medium-sized shorebird that migrates annually between its breeding grounds on the central Canadian arctic tundra and four wintering regions: the Southeast United States (U.S.)/Caribbean, the Northwest Gulf of Mexico, the northern coast of South America, and Tierra del Fuego (Argentina and Chile) at the southern tip of South America. During both the northbound (spring) and southbound (fall) migrations, red knots rely on key staging and stopover areas[2] to rest and feed. A full treatment of the rufa red knot's biology, with references and maps, can be found in the final listing rule supplemental document (USFWS 2014). For an overview of red knot biology, see Appendix A, Supplemental Document Summary.

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[1] The ESA defines the term "species" to include subspecies of fish or wildlife or plants, as well as distinct population segments for vertebrates. Thus, in this document we use the term "species" to refer to the rufa red knot even though the listed taxon is a scientifically classified as a subspecies.

[2] As per Warnock (2010), stopover habitat is defined in this document as places where migrant birds stop to rest, drink, and eat, while staging areas are defined as those stopover sites with abundant, predictable food resources where birds prepare for an energetic challenge (usually a long flight over a barrier such as an ocean or a desert) requiring substantial fuel stores and physiological changes without which significant fitness costs are incurred.

2. **Threats assessment:** The rufa red knot faces numerous threats[3] across its range on multiple geographic and temporal scales. These threats are affecting the species now and will continue to have species-level effects into the future (79 FR 73705-73748). A full analysis of threats, with references, can be found in the supplemental listing document (USFWS 2014). For an overview of threats, see Appendix A, Supplemental Document Summary. A framework for classifying threats is given in table 1, and a classification of threats to the red knot is given in table 2. In the final listing rule, the Service determined that the rufa red knot is threatened under the ESA due to the following primary threats: loss of breeding and nonbreeding habitat; likely effects related to disruption of natural predator cycles on the breeding grounds; reduced prey availability throughout the nonbreeding range; and increasing frequency and severity of asynchronies (mismatches) in the timing of the birds' annual migratory cycle relative to favorable food and weather conditions. These threats that are driving the red knot's status as a threatened species under the ESA are classified as High Severity in table 2.

   In the final listing rule the Service also evaluated other, secondary factors that likely cause additive red knot mortality. Individually the secondary factors are not expected to have species-level effects. Cumulatively, however, these factors are expected to exacerbate the effects of the primary threats, as they further reduce the species' resiliency, including its adaptive capacity. These secondary factors include hunting; predation in nonbreeding areas; harmful algal blooms; and human disturbance, oil spills, and wind energy development especially near the coasts. These secondary threats are classified as Moderate Severity in table 2.

   Classified as Low Severity in table 2 are those threats that were evaluated in the final listing rule, but which the Service concluded are not contributing to the red knot's threatened status under the ESA.

   Note that the classifications in table 2 are based on the Service's rangewide assessment of threats to the red knot. Due to geographic variability, management priorities in a particular local area may differ from those shown in table 2. For example, in an area with abundant intertidal habitat that is not facing any imminent threats, addressing coastal engineering or development may be a lower priority than managing a localized predator problem, despite the fact that, at a rangewide scale, the Service considers coastal engineering/development more urgent than predation in nonbreeding habitats.

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[3] The Service defines "threat" as any action or condition that is known to or is reasonably likely to negatively affect individuals of a species. This includes those actions or conditions that have a direct impact on individuals, as well as those that affect individuals through alteration of their habitat or other required resources. Depending on the context, we use the term "threat" as a general term to describe—either together or separately—the source of the action or condition that negatively affects the species (e.g., housing development), or the action or condition itself, which includes direct impacts (e.g., disturbing individuals) and stressors (e.g., habitat or resource loss). The mere identification of "threats" is not sufficient to compel a finding that a species meets the statutory definition of an endangered species or of a threatened species. Describing the negative effects of the threats in light of the exposure, timing, and scale at the population and species levels provides a clear basis upon which we make a listing determination. Such an assessment was conducted in the red knot listing final rule and supplemental document.

Table 1. Threat classification categories

Life Phase	Breeding (B) Migration (M) Wintering (W)
Severity	High - threat is driving ESA threatened status Moderate - threat causes additive mortality and/or negative synergistic effects Low - minor or potential threat
Certainty	High - Very likely to occur/continue and to impact species in predictable ways Moderate - Very likely to occur/continue, but species impacts are not well known or are unpredictable Low - Likelihood of threat occurring/continuing is uncertain and/or severity of impacts is uncertain
Scope	Rangewide - includes threats that act throughout either the breeding or nonbreeding range, but may not act across both Regional - threats that act across an entire wintering region or migration flyway; or across a substantial portion of a wintering region, flyway, or the breeding range Local - threats that act at the scale of a discrete action or activity, or a geographic clustering of actions or activities
Urgency of Management Response	High - immediate need, 1 to 3 years Moderate - 3 to 5 years Low - 6+ years
Manageability	Short-term - action at a local or regional scale can abate this threat within 10 years Long-term - action at a local or regional scale can abate this threat within 25 years Intractable - this threat cannot be directly abated by action at the geographic and temporal scales considered in recovery plans. However, monitoring may be important, and abating other threats may indirectly help by increasing the species' adaptive capacity to cope with this threat (i.e., by sustaining/enhancing resiliency, redundancy, and/or representation*)

* Resiliency refers to the capacity of a population to withstand stochastic disturbance events. Redundancy spreads risk among multiple populations to minimize the potential loss of the species from catastrophic events. Representation refers to the conservation of a species within the array of different environments in which it occurs, or areas of significant geographic, genetic, or life history variation, termed "ecological settings." Together, these "3Rs," and their core parameters of demographics, distribution, and diversity, are the essential characteristics that contribute to a species' ability to sustain populations in the wild over time.

Table 2. Classification of threats to the red knot

Threat	Life Phase	Severity	Certainty	Scope	Urgency of Management Response*	Manageability
Sea level rise	MW	High	High	Rangewide	NA	Intractable**
Coastal engineering***	MW	High	High	Regional	High	Long-term
Coastal development	MW	High	High	Rangewide	High	Long-term
Beach cleaning	MW	Low	High	Regional	Low	Short-term
Invasive vegetation	MW	Moderate	High	Regional	Moderate	Short-term
Agriculture	MW	Low	Low	Local	Low	Long-term
Aquaculture	MW	Moderate	High	Local	High	Short-term
Arctic ecosystem change	B	High	Moderate	Rangewide	NA	Intractable
Arctic human development	B	Low	Low	Local	Moderate	Long-term
Sport hunting	MW	Low	Moderate	Regional	Low	Short-term
Subsistence hunting	MW	Moderate	Low	Regional	Moderate	Short-term
Research activities	MW	Low	High	Local	Low	Short-term
Parasites	BMW	Low	Low	Rangewide	NA	Intractable
Disease	BMW	Low	Moderate	Rangewide	NA	Intractable
Predation in nonbreeding areas	MW	Moderate	High	Rangewide	Moderate	Short-term
Predation in breeding areas	B	High	Moderate	Rangewide	NA	Intractable
Reduced nonbreeding food availability from marine ecosystem change (e.g., ocean acidification, ocean warming, marine diseases/ parasites/ invasive species)	MW	Moderate	Low	Rangewide	NA	Intractable
Reduced nonbreeding food availability from proximate human activity (e.g., marine harvest, sand placement, beach driving)	MW	High	High	Regional	High	Short-term
Timing asynchronies	BMW	High	Moderate	Rangewide	NA	Intractable
Human disturbance	MW	Moderate	High	Regional	High	Short-term
Competition with gulls	M	Low	Low	Local	Low	Long-term
Wind energy development	MW	Moderate	Moderate	Regional	High	Short-term
Harmful algal blooms	MW	Moderate	Low	Regional	NA	Intractable
Oil spills	MW	Moderate	Moderate	Regional	High	Long-term

* Urgency is not applicable (NA) to intractable threats.

** The accelerating global and regional rates of sea level rise cannot be slowed by direct action under a recovery plan. However, recovery actions can include responses to sea level rise aimed at slowing or offsetting habitat impacts. For example, living shorelines or beach nourishment projects may help retain or restore intertidal habitats impacted by sea level rise.

*** Coastal engineering includes all activities described under Shoreline Stabilization in the supplemental listing document, such as hard structures, beach nourishment, and dredging. Such activities are often, but not always, conducted in response to sea level rise. Such practices are known to exacerbate losses of intertidal habitats by blocking their migration. When not precluded by human interventions, landward and/or longshore migration of intertidal habitats is the natural, geologic response of many coastal systems under rates of slow to moderate sea level rise (USFWS 2014). See Factor A in Appendix A, Supplemental Document Summary.

3. **Conservation assessment:** The supplemental listing document describes a historical decline in red knots in the United States caused by overhunting throughout the 1800s. Following passage of the Migratory Bird Treaty Act in 1918 (40 Stat. 755; 16 U.S.C. 703-712) (MBTA), red knot numbers appeared to rebound during the first half of the 20th century. It is unclear whether the red knot population fully recovered its historical abundance following the period of unregulated hunting, and it is possible this episode reduced the species' resilience to face other threats that emerged over the rest of the 20th century. This era of intensive hunting has also been implicated as one factor, along with coastal development, that may have led to changing use of spring stopover areas along the Atlantic coast, possibly including increased reliance on Delaware Bay (USFWS 2014).

   It was the discovery of a massive shorebird stopover phenomenon in Delaware Bay in the early 1980s that led to the first major milestone in red knot conservation since passage of the MBTA almost 70 years earlier. In 1986, Delaware Bay was designated the first site in the Western Hemisphere Shorebird Reserve Network (WHSRN) due to its hemispheric significance to red knots and several other shorebird species. Shorebird use of Delaware Bay hinges on a superabundance of horseshoe crab (*Limulus polyphemus*) eggs, which the birds feed on to quickly regain weight lost on long migration flights. Subsequent WHSRN designations have included important red knot sites in Chile, Argentina, Brazil, the United States, and Canada. Partners associated with WHSRN, which is coordinated by the nonprofit Manomet Center for Conservation Science (Manomet), have been spearheading shorebird conservation across this network, which now includes most major red knot stopover and wintering areas.

   Delaware Bay was not known as a major shorebird stopover area until the early 1980s, despite earlier detailed shorebird studies in the South Jersey region. It is unclear if the large magnitude of the shorebird-horseshoe crab phenomenon was simply missed by science until the early 1980s, or if the distribution of red knots and other shorebirds changed over the period of the historical record. For much of the early and mid-20th century, the shorebird phenomenon in Delaware Bay may have been much reduced (relative to 1980s levels), and therefore easier to miss, due to the occurrence of low points in the abundance of both shorebirds (caused by previous overhunting, as mentioned above) and horseshoe crabs (caused by intensive harvest for fertilizer and livestock feed). Alternatively, it may be that the red knot did not make extensive use of Delaware Bay prior to its population decline a century ago. Under this scenario, red knots came to rely on Delaware Bay because their populations were recovering at the same time that Atlantic-side stopover habitats in the region were becoming developed and the shorelines stabilized. This second theory is supported by the fact that the spring stopover was historically more spread out along the mid-Atlantic, rather than highly concentrated as it is now (e.g., in Delaware Bay and Virginia). We have no means to determine how long shorebirds may have been reliant on horseshoe crab eggs in Delaware Bay prior to the early 1980s (USFWS 2014).

   Following discovery of the importance of Delaware Bay, annual spring counts have been conducted across this key staging area since the early 1980s, as have extensive bird marking and research efforts. This work in Delaware Bay is led by the States of New

Jersey and Delaware in partnership with the Service and numerous agency, academic, and conservation groups from around the world. One of those partners, the Canadian Wildlife Service, documented the southernmost (and historically the largest) red knot wintering area in Argentina and Chile (particularly the island of Tierra del Fuego that spans both countries) during a comprehensive South American shorebird survey from 1982 through 1985. Various partners have subsequently documented three other major wintering regions and numerous migration stopovers across the red knot's range. Among the most important nonbreeding habitats now known are James Bay, the Nelson River Delta, and Mingan Islands, Canada; parts of the Atlantic coast in Massachusetts and New Jersey; the Virginia barrier islands; Kiawah Island, South Carolina; the mouth of the Altamaha River in Georgia; Florida's central Gulf coast; Laguna Madre in Texas; the Maranhão region on Brazil's north coast; Lagoa do Peixe on Brazil's Atlantic coast; several sites along the Patagonian coast of Argentina; and Tierra del Fuego (USFWS 2014).

Delaware Bay was also the focus of the next major threat to red knot populations, as well as the birthplace of the modern-day red knot conservation effort. The 1990s saw steep increases in the harvest of horseshoe crabs, this time for the bait and biomedical industries. Shorebird numbers in Delaware Bay saw modest declines in the 1990s (see Appendix B), and several lines of emerging research indicated that reduced availability of horseshoe crab eggs was negatively impacting rates of shorebird weight gain and survival. By 1998, the Atlantic States Marine Fisheries Commission (ASMFC) adopted the first Fishery Management Plan for horseshoe crabs. This is the first and still the only ASMFC plan aimed at managing a harvested species specifically to protect a dependent species—the red knot. Unfortunately, red knot numbers in Delaware Bay and Tierra del Fuego continued to drop—now precipitously—through the mid-2000s (see Appendix B), resulting in petitions for ESA listing starting in 2004. By 2012, red knot numbers appear to have stabilized, though at a much reduced level relative to the 1980s (Appendix B). The horseshoe crab bait harvest has been adequately managed since 2013. A timeline of major conservation efforts and milestones is given in table 3.

Table 3. Chronological milestones in red knot conservation

1918 – Passage of the MBTA appears to have reversed red knot population declines that occurred through the 1800s due to over hunting in the United States.

1986 – Delaware Bay designated the first WHSRN site, a few years following discovery that a superabundance of horseshoe crab eggs along the bayshores was supporting red knots and other shorebirds in the hundreds of thousands each May. Designation of many other WHSRN sites important to red knots followed.

1986 – Annual shorebird surveys and studies began in Delaware Bay. These continue to the present day.

1989 – Atlas of Nearctic Shorebirds on the Coast of South America published by Environment Canada, providing the first documentation of major red knot wintering areas.

1994 – Comprehensive Management Plan for Shorebirds on Delaware Bay prepared by the New Jersey Department of Fish, Game and Wildlife. This plan established a Shorebird Working Group that met regularly through the 1990s.

1997 – The book *Flight of the Red Knot* published for the popular press.

1997 – Delaware Bay Shorebird Project established by the States of New Jersey and Delaware with agency, research, and conservation partners from around the world. Still in operation, the project coordinates red knot trapping and marking for a variety of research and conservation purposes. Several partners have since assisted with establishment of red knot research and conservation programs across the species' range. Programs are now in place in Canada, Massachusetts, Virginia, South Carolina, Georgia, Florida, Texas, Brazil, Argentina, and Chile.

1998 – ASMFC Horseshoe Crab Management Plan adopted, with key revisions in 2000, 2004, and 2006 to reduce bait harvest, establish closed seasons, and restrict harvest of females.

1999 – Workshop convened by ASMFC that lead to bait-saving devices and reduced demand for horseshoe crab harvest.

2000 – Canadian Shorebird Conservation Plan prepared by the Canadian Wildlife Service.

2001 – U.S. Shorebird Conservation Plan prepared by Manomet and numerous partners. Stepped-down regional plans were subsequently prepared for all of the red knot's U.S. range. This plan established a U.S. Shorebird Conservation Partnership Council with agency and conservation members; the Council is still active.

2001 – Shorebird Technical Committee established by the Service and the ASMFC to address the need for shorebird expertise in the horseshoe crab management arena. The Committee released a peer reviewed assessment report in 2003. An updated version of the Committee is still in operation.

2001 – Carl N. Shuster Jr. Horseshoe Crab Reserve established off the mouth of Delaware Bay by the National Marine Fisheries Service.

2003 – New Jersey instituted closures of certain Delaware Bay beaches to public access during the red knot stopover season. Public viewing areas have subsequently been designated and staffed by conservation groups and volunteers who provide education on shorebirds.

2004 – Final Natural Resource Restoration Plan for the 1996 *Anitra* oil spill allocated $550,000 for shorebird habitat enhancement and other conservation efforts in Delaware Bay and South America.

2006 – Red knot designated a candidate for listing under the ESA based on threats as well as recent (sharp and ongoing) population declines in Tierra del Fuego and Delaware Bay (see Appendix B).

2007 – Red Knot Conservation Plan for the Western Hemisphere prepared by WHSRN, updated in 2010.

2007 – Québec Shorebird Conservation Plan released.

2008 – Delaware Shorebird Conservation Plan prepared by Delaware Division of Fish and Wildlife.

2008 – Red knot genetics study initiated in partnership between the Service and the U.S. Geological Survey. resume report was completed in 2019.

2008 – Status of the Red Knot in the Western Hemisphere (Studies in Avian Biology No. 36) published. This comprehensive publication by numerous authors was based largely on a status assessment prepared for the Service in 2007.

Table 3. Chronological milestones in red knot conservation

2009 – Bandedbirds.org established by New Jersey Audubon Society and other partners, to house resighting data for uniquely marked red knots and other species. The database and public reporting web site are still in operation, and now provide important data inputs to the ASMFC's current horseshoe crab management framework.

2009 – Red Knot Working Group established by Manomet and the Conserve Wildlife Foundation of New Jersey (CWFNJ). The group included research and conservation partners from across the red knot's range, and met in 2009 and 2011.

2009 – Recovery Plan for Red Knot, *rufa* subspecies, in Newfoundland and Labrador (Canada) released.

2010 – National Fish and Wildlife Foundation (NFWF) 10-Year Business Plan for Conservation of the Red Knot released.

2010 – Service's Red Knot Spotlight Species Action Plan released.

2010 – First red knot geolocator data published, revealing new information on migration.

2010 – Red knots declared endangered in Argentina. With only Federal guidelines, each Argentinean province enacts its own specific laws. Two of Argentina's Patagonian provinces have declared the conservation of migratory shorebirds to be "in the Provincial interest" and made it illegal to modify wetland habitats important for shorebirds.

2012 – Addendum VII to the ASMFC Horseshoe Crab Management Plan adopted scientific modeling and an adaptive management approach to the bait harvest in Delaware Bay. This approach is known as Adaptive Resource Management, or ARM.

2012 – Service's Piping Plover Wintering Strategy released, including numerous conservation actions that will incidentally benefit red knots along the U.S. Southeast and Gulf coasts. The strategy was adopted as part of the Service's Northern Plains Piping Plover Recovery Plan in 2016.

2012 – Two books published for the popular press—*Moonbird: A Year on the Wind with the Great Survivor B95*, and *Life Along the Delaware Bay: Cape May, Gateway to a Million Shorebirds*.

2013 – France adopted full protection for the red knot and removed it from the list of hunted species in Guadeloupe, Martinique, and Saint-Martin. The red knot was also protected in French Guiana in 2014.

2014 – Rufa red knot elevated to Appendix I of the Convention on Migratory Species, which recommends strict protection.

2015 – Rufa red knot listed as threatened under the ESA.

2015 – Atlantic Flyway Shorebird Initiative (AFSI) Business Plan released, which includes red knot as 1 of 15 focal species. Key actions focus on habitat, predation, human disturbance, hunting, and knowledge gaps.

2015 – The book *The Narrow Edge: A Tiny Bird, an Ancient Crab, and an Epic Journey* published for the popular press.

2015 – Pilot efforts test satellite transmitters for use in tracking red knots.

2016 – Service's Programmatic Biological Opinion for structural aquaculture issued. This Opinion assessed impacts from continued and expanded intertidal and nearshore aquaculture, and set up a 10-year adaptive management process covering about 6 miles of Delaware Bayshore in Cape May County, New Jersey.

2016 – Recovery Strategy and Management Plan for the Red Knot in Canada prepared, following addition of the red knot to Canada's list of Species at Risk in 2012. The plan was finalized in 2017.

2016 – State and Federal agencies initiated an annual meeting to review and discuss red knot conservation in Delaware Bay.

2016 – National wildlife refuges in the Service's Northeast Region began work on Best Management Practices for Evaluating and Managing Anthropogenic Disturbances to Migrating Shorebirds on Coastal Lands in the Northeastern United States.

2017 – The CWFNJ and other partners held a workshop to review 20 years of research and conservation projects under the Delaware Bay Shorebird Project, and plans for future work. A summary publication is planned.

2017 – First red knot nanotag data published, revealing new information on red knot movements.

2017 – The CWFNJ funded to develop a framework for flyway-wide and site-based targets and metrics to assess the recovery of red knots.

4. **Summary statement:** The red knot is a medium-sized, highly migratory shorebird that ranges across nearly the full latitude gradient of the Western Hemisphere. The red knot is among the longest-distance migrants in the animal kingdom, and among the best-studied shorebirds in the world. This species apparently recovered from a period of substantial decline caused by overhunting in the United States in the 1800s. Through the second half of the 20th century, still rebounding red knot populations coped with rapid coastal development, and with a low point in horseshoe crab abundance caused by intensive harvest for fertilizer and livestock feed. As both red knot and horseshoe crab populations rebuilt over these decades, the knots may have responded to Atlantic coast development by increasing their reliance on a single spring stopover site, Delaware Bay,[4] where, by the early 1980s, a superabundance of horseshoe crab eggs was fueling the birds' rapid regain of weight lost on long migration flights. During the 1990s, an active conservation constituency began to take shape in response to a new round of horseshoe crab overharvest, which threatened the continued viability of Delaware Bay as a staging area by decreasing egg supplies. Under the current management framework (i.e., the ARM), the present horseshoe crab harvest is not considered a threat to the red knot because harvest levels are tied to red knot populations via scientific modeling. Most data suggest that the volume of horseshoe crab eggs is currently sufficient to support the Delaware Bay's stopover population of red knots at its present size. However, because of the uncertain trajectory of horseshoe crab population growth, it is not yet known if the egg resource will continue to adequately support red knot population growth over the next decade.

   Over the past 25 years, the red knot conservation constituency has grown and expanded and now spans the species' range. However, new threats have also come to light. Some of these threats may have exacerbated past declines that were primarily attributed to the horseshoe crab harvest. Other emerging threats may be hindering a rebound in red knot numbers, particularly in the longest-migrating birds that winter in Tierra del Fuego. Still other threats, largely driven by climate change, have only recently begun increasing in severity but raise significant concerns about the ability of the red knot to recover from the decline it experienced in the 1990s and 2000s. Some intractable threats— such as accelerating sea level rise; marine and Arctic ecosystem changes; and life cycle timing mismatches with food or weather conditions—cannot be directly abated by action at the geographic and temporal scales considered in species recovery plans under the ESA. However, research and monitoring can provide important insights into how such threats are unfolding, and into the red knot's adaptive capacity to cope with these threats. Further, abating other threats that <u>can</u> be managed by direct action will be important, by acting to bolster this species' adaptive capacity through sustaining or enhancing resiliency, redundancy, and/or representation.

[4] It is possible that horseshoe crab populations also became more concentrated in Delaware Bay, as a result of Atlantic coast development and/or the mid-20th century fertilizer harvest.

C. PRELIMINARY RECOVERY STRATEGY

1. **Recovery priority number:** The red knot is assigned a recovery priority number of 12C, which indicates this species faces a moderate degree of threat and low recovery potential. Four factors influence the assignment of the recovery priority number: degree of threat, recovery potential, taxonomy, and potential for conflict.

   The degree of threat to the rufa red knot is considered moderate, which means the species will not face extinction if recovery is temporarily held off, although there may be continued population declines or threats to habitat. The classification as moderate is supported by the population trend information and threats assessment in the supplemental listing document (USFWS 2014). Both population declines and threats are substantial and well documented, but populations appear to have stabilized (at a low level) since about 2012 (see Appendix B). Best available data indicate that more than 49,000 red knots stopped in Delaware Bay in spring 2017 (Lyons 2017), and additional birds are known to skip this staging area (USFWS 2014). In addition, the Delaware Bay horseshoe crab harvest, which is considered a primary causal factor in the decline of the red knot population in the 1990s and 2000s, is now considered adequately managed with harvest levels tied to red knot populations via scientific modeling. Thus, the red knot does not meet the definition of a high degree of threat, which is reserved for species for which extinction is almost certain in the immediate future because of a rapid population decline or habitat destruction. Likewise, the red knot does not fit the low threat category, which is for species facing a population decline which may be a short-term, self-correcting fluctuation, or when the impacts of the threats to the species are not fully known (48 FR 43104).

   Recovery potential is considered low because many of the threats driving the red knot's listed status are intractable, and many other important threats can be abated only through long-term actions at large spatial scales. In addition, several key threats are associated with considerable uncertainty, as shown in table 2.

   Based on Service policy (48 FR 43104), a listed subspecies classified as moderate degree of threat and low recovery potential is assigned a recovery priority number of 12 (on a scale from 1 to 18). According to this policy, the recovery priority number is modified with a "C" to give additional priority to those species that are, or may be, in conflict with construction or other development projects or other forms of economic activity. The red knot is assigned a recovery priority number of 12C because of the past history and future potential for conservation of this species to be in conflict with harvest of horseshoe crabs and other marine species, intertidal aquaculture, coastal development, shoreline stabilization, and beach recreation.

2. **Recovery vision statement:** Full recovery of the red knot will be achieved when the following conditions are met. This is a preliminary vision. More details, including quantitative targets, will be developed for the full recovery plan.

   (1) populations within all four wintering regions (Argentina/Chile,[5] northern South American coast, northwestern Gulf of Mexico, and southeastern United States/Caribbean) are sufficiently large and stable, based on adequate surveys and monitoring, and on scientific modeling such as a full-life-cycle population viability analysis (PVA) *[resiliency, representation]*;

   (2) rates, trends, and trajectories of adult survival, juvenile survival, and reproduction are adequately understood (including consideration of Arctic ecosystem change), and are sufficient to support the resilient wintering populations described in (1), above *[resiliency]*;

   (3) the rufa subspecies breeding and nonbreeding distributions are well understood and delineated relative to other subspecies, and the rufa population structure is clarified (e.g., genetic relationships among subspecies, and among the rufa wintering regions) *[resiliency, representation]*;

   (4) a network of key wintering habitats and major spring and fall migration staging areas across North America and South America provides sufficient suitable food resources at the appropriate times in the annual cycle and is adequately managed and protected *[resiliency, representation]*; and

   (5) migration stopover habitats across the range (in addition to the key staging areas) are sufficient to allow red knots to adapt to short-term (e.g., annual weather, food, predation, disturbance conditions) and long-term (e.g., climate change, sea level rise, habitat modification) changes in their migratory landscape and timing, and are adequately managed and protected *[redundancy, representation]*.

3. **Preliminary action plan:**

   We have identified the following near-term actions that various Service programs can take to abate the manageable threats listed in table 2. This action plan provides interim guidance to Service offices and programs on how red knot recovery can be advanced until a recovery plan is developed and approved in an estimated 2 to 4 years. Note that additional actions will likely be identified in the full recovery plan. Further note that, due to several important but intractable threats listed in table 2, even full implementation of the recovery plan may or may not be sufficient to achieve recovery of this species under the ESA.

[5] Although numerical targets have not yet been developed for the four wintering regions, it is clear that considerable growth in the Argentina/Chile wintering population will be necessary to achieve recovery; see Appendix B. This wintering population is substantially reduced relative to the 1980s and 1990s, and appears to face the greatest risk of extirpation.

Although a rangewide perspective will be essential to recovery planning, we expect most Service efforts in the near term will focus on coastal (intertidal) habitats from Maine to Texas. The actions marked with an asterisk (*) below will be focused primarily in these areas, though they may also have some applicability in inland, offshore, and/or international parts of the red knot range.

1. Support, encourage, and, if possible, fund the research priorities listed in U.S. Fish and Wildlife Service Rufa Red Knot Research Priorities, 2019 to 2022.

2. *In Delaware Bay, continue the Service's active role in horseshoe crab management, in the management of intertidal aquaculture, and in supporting State-led efforts to monitor and protect red knots, with a goal of steadily increasing the percent of red knots that depart the bay at adequate weights even as numbers of knots using the bay also increases.

3. *Avoid and minimize loss and degradation of nonbreeding habitat from coastal engineering and development.
   a. Work through the Atlantic Flyway Shorebird Initiative's (AFSI) Coastal Engineering Committee (Habitat Work Group) to develop best practices.
   b. Work with the U.S. Army Corps of Engineers (Corps) and the States to adopt the best practices at the landscape- and project-level scales (e.g., through sections 7(a)(1) and 7(a)(2) of the ESA).
   c. Focus on documented red knot staging areas, as well as regularly used stopover and wintering habitats. When possible, pursue multispecies conservation opportunities that also benefit other State or federally listed species.

4. *Work with partners to preserve, enhance, and restore nonbreeding habitat, both proactively and incidental to engineering and development projects. For example, carefully planned beach nourishment can increase or improve red knot habitat in some areas, such as parts of Delaware Bay.

5. *Develop Service recommendations for managing recreation and other sources of human disturbance in red knot nonbreeding habitats. In developing the recommendations, build on related work being done by the National Wildlife Refuge System, through the AFSI's Human Activities Committee (Habitat Working Group), and in the piping plover wintering range. Work with land managers and project proponents to implement the Service recommendations. Also work with recreation user groups (e.g., fishermen) to enlist support for minimizing disturbance of red knots.

6. *Work with partners to monitor and manage invasive vegetation in red knot nonbreeding habitats.

7. *Work with land managers to evaluate gull and raptor management in the vicinity of red knot nonbreeding habitats on a case-by-case basis. In some instances, management adjustments may be warranted, such as relocating peregrine falcon

(*Falco peregrinus*) nesting structures. Build on the AFSI's forthcoming shorebird predation best management practices.

8. *Work with the U.S. Coast Guard and other partners to identify key red knot habitats in oil spill response planning, and prioritize these areas for protection in the event of a spill.

9. *Work with wind energy developers and regulators to explore alternatives to siting new turbines in red knot concentration areas or along major migration pathways.

10. *Work with all States, Service Regions, and the U.S. Geological Survey's Bird Banding Lab to ensure best practices are followed by all individuals and entities engaged in red knot trapping, marking, and other research.

11. Establish a Red Knot Information Partnership of interested species experts, researchers, and conservation practitioners from across the species' range. Facilitate the exchange of information by establishing an email listserve and perhaps other electronic tools/platforms. Hold an annual conference call or webinar to discuss collaborative research, new advances in red knot science, new information about threats, and new developments in conservation. Hold ad hoc conference calls or webinars to address urgent issues as they arise.

12. Enhance and facilitate international cooperation on red knot research and conservation.

D. PREPLANNING DECISIONS

The Service will prepare a single-species recovery plan for the red knot, following preparation of a Biological Report and a Species Status Assessment (SSA). The supplemental listing document (USFWS 2014), with updates, will serve as the foundation for the Biological Report. The purpose of the Biological Report will be to summarize the vast amount of information on red knot biology and threats relevant to conservation of this species. The Biological Report will be updated periodically (target: at least every 5 years).

The first iteration of the Biological Report will also serve to inform the SSA. An SSA is a focused, repeatable, and rigorous scientific assessment of a species' status. The SSA framework includes evaluation of the species' needs, its current condition, and its future condition over the range of plausible future scenarios. The SSA uses the conservation biology principles of resiliency, redundancy, and representation as a lens to evaluate the current and future conditions of the species. As a result, the SSA characterizes a species' ability to sustain populations in the wild over time based on the best scientific understanding of current and future abundance and distribution within the species' ecological settings. We expect to build on existing population modeling for the red knot (e.g., from the ARM) to develop a full PVA that, along with the Biological Report, will provide a robust informational foundation for the SSA.

The Service's lead biologist for the red knot will be responsible for SSA and recovery plan coordination. This will entail preparation of the Biological Report, the SSA, and the recovery plan, with assistance from other Service offices and programs and state and other outside experts. The technical work of the PVA will be conducted by outside modeling experts (e.g., via contract, cooperative agreement, or interagency agreement). The administrative record for the SSA and the recovery plan will be housed at the New Jersey Field Office. Information sources for all of the products referenced above will be maintained by the Service's lead biologist and housed in Service-wide networks (i.e., Sharepoint, RefWorks).

A Recovery Team will not be appointed, but the Service will widely solicit and thoroughly consider the individual expertise of red knot experts and conservation practitioners. This will be accomplished by various means such as engagement with individuals, workshops, webinars, and through the Red Knot Information Partnership.

Target dates are as follows:
3Rs Analysis - 2019
Update Biological Report and Develop Recovery Targets - 2020
Final Recovery Plan - 2021

Key stakeholders are listed in table 4. The stakeholder involvement strategy includes engagement with individual experts and conservation practitioners; communication through the Red Knot Information Partnership; presentations at conferences, workshops, and meetings; perhaps convening workshops or web-based meetings on specific recovery topics; and both formal and informal communications with States, tribes, and other countries.

Signed: ______________________ Date 9 April 2019

Acting *Regional Director, Northeast Region*

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Table 4. Key stakeholders in red knot recovery

All national, state, provincial, local, and tribal governments within the rufa red knot range
American Littoral Society
Atlantic Flyway Shorebird Initiative
Atlantic States Marine Fisheries Commission
Audubon Louisiana
Audubon North Carolina
Bahamas National Trust
Bandedbirds.org
Barataria-Terrebonne National Estuary Program
Bird Studies Canada
Birds Caribbean
British Trust for Ornithology
Centro Nacional de Pesquisa e Conservação de Aves Silvestres, Brazil
Citizens United for the Maurice River, New Jersey
Coastal Bend Bays & Estuaries Program, Texas
College of William and Mary's Center for Conservation Biology
Comisión Nacional del Medio Ambiente, Chile
Conserve Wildlife Foundation of New Jersey
Cornell Lab of Ornithology's eBird database
Delaware Museum of Natural History
Florida Shorebird Alliance
Fundación Inalafquen, Argentina
Georgia Shorebird Alliance
Groupe d'Études et de Protection des Oiseaux de Guyane, French Guiana
Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Brazil
Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Brazil
International Wader Study Group
Kiawah Island Conservancy, South Carolina
LJ Niles, LLC
Manomet Center for Conservation Science
National Audubon Society
National Estuarine Research Reserves (U.S.)
National Fish and Wildlife Foundation
National Marine Fisheries Service (NOAA)
National Park Service (U.S.)
National Wildlife Refuges (U.S.)
Natura Patagonia, Chile
New Jersey Audubon Society
North Carolina Waterbird Management Committee
Panama Audubon
Royal Ontario Museum, Canada
Rutgers University, New Jersey
State University of New York College of Environmental Science and Forestry
The Nature Conservancy
U.S. Army Corps of Engineers
U.S. Coast Guard
U.S. Fish and Wildlife Service's Migratory Birds, Fisheries, and Coastal Programs
U.S. Geological Survey
U.S. Shorebird Conservation Partnership Council
Universidad Santo Tomás, Chile
Virginia Tech Shorebird Program and Department of Fish and Wildlife Conservation (Trawl Survey)
Wash Wader Ringing Group
Western Hemisphere Shorebird Group
Western Hemisphere Shorebird Reserve Network

APPENDIX A.

Summary from Rufa Red Knot Background Information and Threats Assessment

See original document (USFWS 2014) for references cited in this summary.

TERMINOLOGY: Throughout this document, "rufa red knot," "red knot," and "knot" are used interchangeably to refer to the subspecies *Calidris canutus rufa*. "*Calidris canutus*," and "*C. canutus*" are used to refer to the species as a whole or to birds of unknown subspecies. References to other particular subspecies are so indicated by use of the Latin name. "Winter" is consistently used to refer to the nonbreeding period of the red knot life cycle when the birds are not undertaking migratory movements, typically December to February, although this period is actually summer in the Southern Hemisphere. Likewise, although the seasons are reversed in the Southern Hemisphere, "spring" is used throughout to refer to the nonbreeding period of the red knot life cycle when the birds are undertaking northbound migratory movements, and "fall" is used to refer to the nonbreeding period when the birds are undertaking southbound migratory movements.

INTRODUCTION: The rufa red knot (*Calidris canutus rufa*) is a medium-sized shorebird that migrates annually between its breeding grounds in the central Canadian Arctic and several wintering regions, including the Southeast United States (Southeast), the Northwest Gulf of Mexico, northern Brazil, and Tierra del Fuego at the southern tip of South America. During both the northbound (spring) and southbound (fall) migrations, red knots use key staging and stopover areas to rest and feed. Another subspecies, *Calidris canutus roselaari*, breeds in western Alaska and on Wrangel Island in eastern Russia (Carmona *et al.* 2013, p. 169; Buehler and Baker 2005, p. 498) and winters on the Pacific coast from northern Mexico through Panama and possibly farther south (D. Newstead pers. comm. February 13, 2014; Carmona *et al.* 2013, pp. 171, 175). The nonbreeding ranges of these two subspecies are known to overlap in a few locations, and may overlap more broadly. However, geolocator data confirm the existence of distinct breeding areas for the *rufa* and *roselaari* subspecies (D. Newstead pers. comm. February 13, 2014; L. Niles pers. comm. January 4, 2013; Newstead *et al.* 2013, p. 56; Niles *et al.* 2012a, pp. 197–200; Niles *et al.* 2010a, pp. 125–126). The rufa red knot's typical life span is at least 7 years (J. Parvin pers. comm. March 14, 2014; Niles *et al.* 2008, p. 28), with the oldest known wild bird at least 21 years old as of 2014 (Bauers 2014; Jordan 2014). Age of first breeding is at least 2 years (S. Koch, L. Niles, and R. Porter pers. comm. August 12, 2014; Harrington 2001, p. 21).

BREEDING: The red knot breeds in the central Canadian Arctic, from the islands of northern Hudson Bay to the Foxe Basin shoreline of Baffin Island, and west to Victoria Island (Niles *et al.* 2008, pp. 15–16; Morrison and Harrington 1992, p. 73). Potential breeding habitat extends farther north the southern Queen Elizabeth Islands (Niles *et al.* 2008, p. 16). The extent to which rufa red knots from different wintering areas mix on the breeding grounds, and therefore potentially interbreed, is poorly known (Harrington *et al.* 1988, p. 443). Red knots generally nest in dry, slightly elevated tundra locations, often on windswept slopes with little vegetation. Breeding areas are located inland, but near arctic coasts. Nests may be scraped into patches of mountain avens (*Dryas octopetala*) plants, or in low spreading vegetation on hummocky (characterized by knolls or mounds) ground containing lichens, leaves, and moss. After the eggs hatch, red knot chicks and adults quickly move away from high nesting terrain to lower, freshwater wetland habitats. On the breeding grounds, the red knot's diet consists mostly of terrestrial invertebrates such as insects and other arthropods (Niles *et al.* 2008, p. 27; Harrington 2001, p. 11).

Pair bonds form soon after the birds arrive on breeding grounds, in late May or early June, and remain intact until shortly after the eggs hatch (Niles *et al.* 2008, p. 25–26; Harrington 2001, p. 16). Female rufa red knots lay only one clutch (group of eggs) per season, and, as far as is known, do not lay a replacement clutch if the first is lost. The usual clutch size is four eggs, though three-egg clutches have been recorded. The incubation period lasts approximately 22 days from the last egg laid to the last egg hatched, and both sexes participate equally in egg incubation. Young are precocial, leaving the nest within 24 hours of hatching and foraging for themselves (Niles *et al.* 2008, p. 27). Females are thought to leave the breeding grounds and start moving south soon after the chicks hatch in mid-July. Thereafter, parental care is provided solely by the males, but about 25 days later (around August 10) males also abandon the newly fledged juveniles and move south. Not long after, they are followed by the juveniles (Niles *et al.* 2008, p. 14). Breeding success of High Arctic shorebirds such as *Calidris canutus* varies dramatically among years in a somewhat cyclical manner. Two main factors seem to be responsible for this annual variation: abundance of arctic lemmings (*Dicrostonyx torquatus* and *Lemmus sibericus*) (by indirectly affecting predation pressure on shorebirds) and weather (Piersma and Lindström 2004, pp. 63–64; Blomqvist *et al.* 2002, p. 149; Summers and Underhill 1987, p. 169). Growth rate of *C. canutus* chicks is very high compared to similarly sized shorebirds nesting in more temperate climates and is strongly correlated with weather-induced and seasonal variation in availability of invertebrate prey (Schekkerman *et al.* 2003, p. 332).

NONBREEDING RANGE: Geolocator and resightings data show definitively that the *rufa* nonbreeding range includes the entire Atlantic and Caribbean coasts of South America and the Caribbean islands; Chiloé Island on the central Pacific coast of Chile; the Pacific coast of Panama; the North American Gulf and Atlantic coasts from Tamaulipas, Mexico through Quebec, Canada; the interior of South America; and the interior of the United States and Canada west at least as far as the Great Plains (Bimbi *et al.* 2014, pp. 29–31; S. Koch, L. Niles, R. Porter, and F. Sanders pers. comm. August 8 and 12, 2014; Newstead 2014a, p. 19; D. Newstead pers. comm. May 8, 2014; Niles 2014; J. Parvin pers. comm. March 13, 2014; Newstead *et al.* 2013, pp. 55–57; Burger *et al.* 2012b, p. 107; Niles 2012a; Niles *et al.* 2012a, entire; Niles 2011a; Niles 2011b; Niles *et al.* 2010a, entire; Niles *et al.* 2008, p. 19; B. Paxton pers. comm. November 9, 2008; Buehler 2002, p. 42; Morrison and Harrington 1992, p. 77). *Calidris canutus roselaari* also occurs in certain parts of this established *rufa* nonbreeding range. Best available data are limited but suggest that the nonbreeding ranges of *C.c. roselaari* and *C.c. rufa* overlap, at least in Texas during spring and in Panama during winter (D. Newstead pers. comm. May 13, 2014; D. Newstead pers. comm. February 13, 2014; D. Newstead pers. comm. February 11, 2014; D. Newstead pers. comm. August 20, 2012). However, geolocator and resightings data provide strong evidence that *Calidris cantus* on the Pacific coast from northeastern Russia to Las Garzas, Mexico are the *roselaari* subspecies, and we conclude from the best available data that the rufa red knot does not occur in this region of the Pacific (D. Newstead pers. comm. February 13, 2014; Carmona *et al.* 2013, entire; J. Buchanan pers. comm. January 9, 2013).

WINTERING: Wintering areas for the rufa red knot include the Atlantic coasts of Argentina and Chile (particularly the island of Tierra del Fuego that spans both countries), the north coast of Brazil (particularly in the State of Maranhão), the Northwest Gulf of Mexico from the Mexican State of Tamaulipas through Texas (particularly at Laguna Madre) to Louisiana, and the Southeast United States from Florida (particularly the central Gulf coast) to North Carolina (Newstead 2014a, p. 19; Newstead *et al.* 2013, p. 55; L. Patrick pers. comm. August 31, 2012; Niles *et al.* 2008, p 17). Smaller numbers of knots winter in the Caribbean, and along the central Gulf coast (Alabama, Mississippi), the mid-Atlantic, and the Northeast United States (eBird.org 2014; Russell 2014, p. 4; Burger *et al.* 2012b, p. 6; A. Dey pers. comm. November 19, 2012; H. Hanlon pers. comm. November 22, 2012; Niles *et al.* 2012a, entire; L. Patrick pers. comm. August 31, 2012; Morrison and Harrington 1992, p. 77). *Calidris canutus* is also known to winter in Central America, northwest South America, and along the Pacific coast of South America, but it is not yet clear if all these birds are the *rufa* subspecies (Carmona *et al.* 2013, entire). Winter area fidelity appears to be high, with minimal movement of birds among wintering regions (Georgia Department of Natural Resources (GDNR) 2013; BandedBirds.org 2012; Schwarzer *et al.* 2012, p. 729; Niles *et al.* 2008, pp. 9, 55; Harrington *et al.* 1988, p. 441). Researchers often distinguish between those rufa red knots that winter the farthest south (in Argentina and Chile) and therefore undertake the longest-distance migrations ("southern-wintering"), from those that winter farther north in northern Brazil and the Southeast ("northern-wintering"), with some notable physiological and ecological differences between the two groups (B. Harrington pers. comm. November 14, 2013).

MIGRATION BIOLOGY: Each year some red knots make one of the longest distance migrations known in the animal kingdom, traveling up to 19,000 mi (30,000 km) annually. Red knots undertake long flights that may span thousands of miles without stopping. As *Calidris canutus* prepare to depart on long migratory flights, they undergo several physiological changes. Before takeoff, the birds accumulate and store large amounts of fat to fuel migration and undergo substantial changes in metabolic rates. In addition, the leg muscles, gizzard (a muscular organ used for grinding food), stomach, intestines, and liver all decrease in size, while the pectoral (chest) muscles and heart increase in size. Due to these physiological changes, *C. canutus* arriving from lengthy migrations are not able to feed maximally until their digestive systems regenerate, a process that may take several days. Because stopovers are time-constrained, *C. canutus* requires stopovers rich in easily digested food to achieve adequate weight gain (Niles *et al.* 2008, pp. 28–29; van Gils *et al.* 2005a, p. 2609; van Gils *et al.* 2005b, pp. 126–127; Piersma *et al.* 1999, pp. 405; 412) that fuels the next migratory flight and, upon arrival in the Arctic, also fuels a body transformation to breeding condition (Morrison 2006, pp. 610–612). At some stages of migration, very high proportions of entire shorebird populations may use a single migration staging site to prepare for long flights. High fractions of the red knot's rangewide population can occur together at a small number of nonbreeding locations, leaving populations vulnerable to loss of key resources (Harrington 2001, p 22). For example, Delaware Bay provides the final Atlantic coast stopover for a significant majority (50 to 80 percent) of the red knot population making its way to the arctic breeding grounds each spring (Clark *et al.* 2009, p. 90; Brown *et al.* 2001, p. 10). Individual red knots show moderate fidelity to particular migration staging areas between years (French Guiana Regional Scientific Council for Natural Heritage (CSRPN) 2013; Duerr *et al.* 2011, p. 16; Watts 2009a; Harrington 2001, pp. 21–22).

SPRING MIGRATION: Well-known spring stopover areas along the Atlantic coast include Río Gallegos, Península Valdés, and San Antonio Oeste (Patagonia, Argentina); Lagoa do Peixe (eastern Brazil, State of Rio Grande do Sul); Maranhão (northern Brazil); the Southeast United States (e.g., the Carolinas to Florida); the Virginia barrier islands (United States); and Delaware Bay (Delaware and New Jersey, United States) (A. Dey pers. comm. April 21, 2014; Wallover *et al.* 2014, p. 6; GDNR 2013; South Carolina Department of Natural Resources (SCDNR) 2013, p. 36; Cohen *et al.* 2009, p. 939; Niles *et al.* 2008, p. 19; González 2005, p. 14). However, large and small groups of red knots, sometimes numbering in the thousands, may occur in suitable habitats all along the Atlantic and Gulf coasts from Argentina to Massachusetts (Niles *et al.* 2008, p. 29).

Although a few birds may depart before the end of January, the main red knot movement north from Tierra del Fuego occurs in February. The northward migration through South America is typically rapid, with only brief stopovers (Niles *et al.* 2008, p. 15), although longer stops in Argentina (17 to 22 days) have been reported (Musmeci *et al.* 2012, pp. 359–360). Birds moving north from Argentina typically arrive in Brazil in April (Scherer and Petry 2012, p. 46; Niles *et al.* 2008, p. 29). Departure from Brazil tends to occur in the first half of May (Niles *et al.* 2010a, p. 126; Niles *et al*. 2008, pp. 15, 29). Many knots marked in Argentina and Chile are seen on the Atlantic coasts of Florida, Georgia, South Carolina, and North Carolina during, but not before, May (B. Harrington pers. comm. November 14, 2013; GDNR 2013; SCDNR 2013, p. 31). Available data indicate that red knots wintering in the Southeast use at least two different spring migration routes—coastal (moving north along the coast to the mid-Atlantic before departing for the Arctic) and inland (departing overland for the Arctic directly from the Southeast coast) (Bimbi *et al.* 2014, pp. 29–30; SCDNR 2013, p. 38; Niles *et al.* 2012a, pp. 197–200; Harrington 2005a, p. 1; Morrison and Harrington 1992, p. 77).

FALL MIGRATION: Departure from the breeding grounds begins in mid-July and continues through August. Females are thought to leave first, followed by males and then juveniles (Niles *et al.* 2008, pp. 14–15; Harrington 2001, p. 6). Adult *Calidris canutus* pass through stopover sites along the migratory route earlier in years with low reproductive success than in years with high reproductive success (Blomqvist *et al*. 2002, p. 149). Along the U.S. Atlantic coast, southbound red knots start arriving in July. Numbers of adults peak in mid-August and most depart by late September, although geolocators and resightings have shown some birds (especially northern-wintering knots) stay through November (Wallover *et al.* 2014, p. 6; Niles *et al.* 2012a, pp. 197–200; Harrington *et al.* 2010b, p. 357; Harrington 2001, p. 2). Well-known fall stopover sites include southwest Hudson Bay (including the Nelson River delta), James Bay, the north shore of the St. Lawrence River, the Mingan Archipelago, and the Bay of Fundy in Canada; the coasts of Massachusetts and New Jersey and the mouth of the Altamaha River in Georgia in the United States; the Caribbean (especially Puerto Rico and the Lesser Antilles); and the northern coast of South America from Brazil to Guyana (eBird.org 2014; Autoridad de Energía Eléctrica (Electric Energy Authority, or (AEE) 2013; Newstead *et al.* 2013, p. 57; Niles 2012a; D. Mizrahi pers. comm. October 16, 2011; Niles *et al.* 2010a, pp. 125–136; Schneider and Winn 2010, p. 3; Niles *et al.* 2008, pp. 30, 75, 94; B. Harrington pers. comm. March 31, 2006; Antas and Nascimento 1996, p. 66; Morrison and Harrington 1992, p. 74; Spaans 1978, p. 72). However, birds can occur all along the coasts in suitable habitats. In one study of northern-wintering red knots, the total time spent along the U.S. Atlantic coast (including spring, fall, and for some birds winter) averaged 218 days (range 121 to 269 days) (Burger *et al.* 2012b, p. 1), or about 60 percent of the calendar year.

MIDCONTINENTAL MIGRATION: Geolocator results from red knots wintering in Texas have shown that these birds typically use a central, overland flyway across the midcontinental United States, with birds departing Texas between May 16 and May 21 and using stopover areas in the Northern Great Plains and along southern Hudson Bay (Newstead *et al.* 2013, p. 58). Texas-wintering birds typically use a similar and direct interior flyway across the midcontinental United States during the southbound migration, using a southbound stopover site on the south shore of Hudson Bay (Nelson River Delta to James Bay). Geolocator results (Bimbi *et al.* 2014, pp. 29–31; Niles 2014; Newstead *et al.* 2013; Niles *et al.* 2012a, p. 197-200; Niles 2011a; Niles 2011b; Niles *et al.* 2010a, pp. 125–128) have suggested that rufa red knots exhibit strong flyway fidelity (Newstead *et al.* 2013, p. 58) (i.e., not switching between Atlantic coast and midcontinental routes). However, newer geolocator data, as yet unpublished, do show some switching between these two flyways. Several Texas-wintering birds have been shown to use the "typical" midcontinental flyway in spring, but then follow a fall migration route along the U.S. Atlantic coast before returning Texas via the Gulf coast. To date, no known geolocator tracks from Texas birds have shown use of the Atlantic coast during spring migration, but some resighting data suggest that this may also occur (D. Newstead pers. comm. May 8, 2014). Even for the same individual bird, the actual routes and number of stopovers can vary considerably from year to year (D. Newstead pers. comm. May 8, 2014). In one study, red knots wintering in the Northwest Gulf of Mexico spent nearly the entire nonbreeding phase of their annual cycle (286 days, or 78.4 percent of the calendar year) on the Texas coast (Newstead *et al.* 2013, p. 55).

NONBREEDING HABITAT: Coastal habitats used by red knots in migration and wintering areas are similar in character (Harrington 2001, p. 9), generally coastal marine and estuarine (partially enclosed tidal area where fresh and salt water mixes) habitats with large areas of exposed intertidal sediments. Migration and wintering habitats include both high-energy ocean- or bay-front areas, as well as tidal flats in more sheltered bays and lagoons (Harrington 2001, p. 9). Preferred wintering and migration microhabitats are muddy or sandy coastal areas, specifically, the mouths of bays and estuaries, tidal flats, and unimproved tidal inlets (North Carolina Wildlife Resources Commission (NCWRC) 2013; Lott *et al.* 2009, pp. 18–19; Niles *et al.* 2008, p. 30; Harrington 2001, p. 8). Along the U.S. Atlantic coast, dynamic and ephemeral (lasting only briefly) features are important red knot habitats, including sand spits, islets, shoals, and sandbars, features often associated with inlets (Harrington 2008, p. 2; Harrington in Guilfoyle *et al.* 2007, pp. 18–19; Winn and Harrington in Guilfoyle *et al.* 2006, pp. 8–10). In many wintering and stopover areas, quality high-tide roosting habitat (i.e., close to feeding areas, protected from predators, with sufficient space during the highest tides, free from excessive human disturbance) is limited (CSRPN 2013; K. Kalasz pers. comm. November 26, 2012; L. Niles pers. comm. November 19 and 20, 2012; Kalasz 2008, p. 9). In nonbreeding habitats, *Calidris canutus* require sparse vegetation to avoid predation (Niles *et al.* 2008, p. 44; Piersma *et al.* 1993, pp. 338–339, 349).

Available information suggests that red knots use inland saline lakes as stopover habitat in the Northern Great Plains (Newstead *et al.* 2013, p. 57; North Dakota Game and Fish Department (NDGFD) 2013; Western Hemisphere Shorebird Reserve Network (WHSRN) 2012;

Skagen *et al.* 1999). We have little information to indicate whether or not red knots may also utilize inland freshwater habitats during migration, but data suggest that certain freshwater areas may warrant further study as potential stopover habitats (C. Dovichin pers. comm. May 6, 2014; eBird.org 2014; Russell 2014, entire). Best available data indicate that small numbers of red knots sometimes use manmade freshwater habitats (e.g., impoundments) along inland migration routes (eBird.org 2014; Russell 2014, entire; Central Flyway Council 2013; NDGFD 2013; Oklahoma Department of Wildlife Conservation (ODWC) 2013; A. Simnor pers. comm. October 15, 2012).

NONBREEDING FOOD: Across all (six) subspecies, *Calidris canutus* is a specialized molluscivore, eating hard-shelled mollusks, sometimes supplemented with easily accessed softer invertebrate prey, such as shrimp- and crab-like organisms, marine worms, and horseshoe crab eggs (Piersma and van Gils 2011, p. 9; Harrington 2001, pp. 9–11). The mollusk prey is swallowed whole and crushed in the gizzard, which in *C. canutus* is the largest (relative to body size) among any shorebird species evaluated (Piersma and van Gils 2011, pp. 9–11). Large gizzards are among this species' adaptations to a mollusk diet, allowing *C. canutus* to grind the hard shells of its prey. *Calidris canutus* prefer thin-shelled to thick-shelled prey species because they are easier to digest and provide a more favorable meat to mass ratio (higher prey quality) (van Gils *et al.* 2005a, p. 2611; Harrington 2001, p. 11; Zwarts and Blomert 1992, p. 113). From studies of other subspecies, Zwarts and Blomert (1992, p. 113) concluded that *C. canutus* cannot ingest prey with a circumference greater than 1.2 in (30 millimeters (mm)). For rufa red knots, prey lengths of 0.16 to 0.79 in (4 to 20 mm) have been observed (Cohen *et al.* 2010b, pp. 359–360; González *et al.* 1996, p. 575). Foraging activity is largely dictated by tidal conditions, as *C. canutus* rarely wade in water more than 0.8 to 1.2 in (2 to 3 cm) deep (Harrington 2001, p. 10). Due to bill morphology, *C. canutus* is limited to foraging on only shallow-buried prey, within the top 0.8 to 1.2 in (2 to 3 cm) of sediment (Gerasimov 2009, p. 227; Zwarts and Blomert 1992, p. 113). Along the U.S. coast, *Donax* and *Mulinia* clams and blue mussel (*Mytilus edulis*) spat are key prey items. A prominent departure from typical prey items occurs each spring when red knots feed on the eggs of horseshoe crabs (*Limulus polyphemus*), particularly during the key migration stopover within the Delaware Bay. Delaware Bay serves as the principal spring migration staging area for the red knot because of the abundance and availability of horseshoe crab eggs (Clark *et al.* 2009, p. 85; Harrington 2001, pp. 2, 7; Harrington 1996, pp. 76–77; Morrison and Harrington 1992, pp. 76–77). In Delaware Bay, horseshoe crab eggs are a superabundant source of easily digestible food.

POPULATION TRENDS: After a thorough review of the best available population data, we conclude that we do not have sufficient reliable data on which to derive a precise rangewide population estimate for the rufa red knot. For example, there are no rangewide population estimates for fall migration or breeding areas because birds are too dispersed. However, we can reliably infer population trend information from some areas. We have high confidence in long-term survey data from two key red knot areas, Tierra del Fuego (wintering) and Delaware Bay (spring), showing declines of 70 to 75 percent over roughly the same period, since about 2000 (Dey *et al.* 2014, p. 2; Dey *et al.* 2011a, p. 2; Clark *et al.* 2009, p. 88; Morrison *et al.* 2004, p. 65; Morrison and Ross 1989, Vol. 2, pp. 226, 252; Kochenberger 1983, p. 1; Dunne *et al.* 1982, p. 67; Wander and Dunne 1982, p. 60). Data sets associated with lower confidence, from the Brazil wintering region and three South American spring stopovers, also suggest declines roughly over this same timeframe (Niles *et al.* 2008, pp. 58, 134; Baker *et al.* 2005, p. 12; González 2005, p. 14; Morrison and Ross 1989, Vol. 2, p. 183; Harrington *et al.* 1986, p. 50), however, more recently a substantial increase was documented in Brazil (Dey *et al.* 2014, p. 1). Emerging information from Virginia also suggests a decline relative to the 1990s (B. Watts pers. comm. August 22, 2014). We do not conclude that the Southeast wintering region has declined over this period despite some years of lower counts in Florida, due to the likelihood that the birds' usage shifts geographically within this region from year to year (Harrington 2005a, pp. 1, 15). In summary, the best available data indicate a sustained decline occurred in the 2000s, and may have stabilized at a relatively low level in the last few years. Attempts to evaluate long-term population trends using national or regional data from volunteer shorebird surveys and other sources have also generally concluded that red knot numbers have declined, probably sharply (National Park Service (NPS) 2013; Andres 2009; Morrison *et al.* 2006, pp. 71, 76–77).

LISTING FACTORS: Under section 4(a)(1) of the Endangered Species Act (the Act), we may list a species based on any of the following five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. We have evaluated each of these five factors.

FACTOR A: Threats to the red knot from habitat destruction and modification are occurring throughout the entire range of the subspecies. These threats include climate change, shoreline stabilization, and coastal development, exacerbated regionally or locally by lesser habitat-related threats such as beach cleaning, invasive vegetation, agriculture, and aquaculture. The subspecies-level impacts from these activities are expected to continue into the future.

Within the nonbreeding portion of the range, red knot habitat is primarily threatened by the highly interrelated effects of sea level rise, shoreline stabilization, and coastal development. The primary red knot foraging habitats, intertidal flats and sandy beaches, will likely be locally or regionally inundated as sea levels rise, but replacement habitats are likely to re-form along eroding shorelines in their new positions (U.S. Climate Change Science Program (CCSP) 2009b, p. 186; Scavia *et al.* 2002, p. 152). However, if shorelines experience a decades-long period of rapid sea level rise, high instability, and landward migration, the formation rate of new foraging habitats may be slower than the rate at which existing habitats are lost (Iwamura *et al.* 2013, p. 6). In addition, low-lying and narrow islands (e.g., in the Caribbean, along the Gulf and Atlantic coasts) may disintegrate rather than migrate, representing a net loss of red knot habitat (Chapter 5 in International Panel on Climate Change (IPCC) 2014, p. 15; Titus 1990, p. 67).

Superimposed on changes from sea level rise are widespread human efforts to stabilize the shoreline, which are known to exacerbate losses of intertidal habitats by blocking their landward migration. About 40 percent of the U.S. coastline within the range of the red knot is already developed, and much of this developed area is stabilized by a combination of existing hard structures and ongoing beach nourishment programs (Rice 2012a, p. 6; Titus *et al.* 2009, p. 5). Hard stabilization structures and dredging degrade and often eliminate existing intertidal habitats, and in many cases prevent the formation of new shorebird habitats (CCSP 2009b, pp. 99–100; Nordstrom 2000, pp. 20, 98–107). Beach nourishment may temporarily maintain

suboptimal shorebird habitats where they would otherwise be lost as a result of hard structures or sea level rise (Nordstrom and Mauriello 2001, entire), but beach nourishment can also have adverse effects to red knots and their habitats (Defeo *et al.* 2009, p. 4; Rice 2009, entire; Peterson *et al.* 2006, entire; Peterson and Bishop 2005, entire; Greene 2002, p. 5). In those times and places where artificial beach maintenance is abandoned (e.g., due to constraints on funding or sediment availability), the remaining alternatives available to coastal communities would likely be limited to either a retreat from the coast or increased use of hard structures to protect development (CCSP 2009b, p. 87; Defeo *et al.* 2009, p. 7). The quantity of red knot habitat would be markedly decreased by a proliferation of hard structures. Red knot habitat would be significantly increased by retreat, but only where hard stabilization structures do not exist or where they get dismantled. Relative to what is known in the United States, little is known about development- related threats to red knot nonbreeding habitat in other countries. However, in some key international wintering and stopover sites, development pressures are likely to exacerbate habitat impacts caused by sea level rise (CSRPN 2013; WHSRN 2012; Niles *et al.* 2008, pp. 17, 19, 73,
97–98; Ferrari *et al.* 2002, p. 39).

Lesser threats to nonbreeding habitat include beach cleaning, invasive vegetation, agriculture, and aquaculture. The practice of intensive beach raking may cause physical changes to beaches that degrade their suitability as red knot habitat (Defeo *et al.* 2009, p. 4; Nordstrom and Mauriello 2001). Although not a primary cause of habitat loss, invasive vegetation can be a regionally important contributor to the overall loss and degradation of the red knot's nonbreeding habitat (U.S. Fish and Wildlife Service (USFWS) 2012a, p. 27; Defeo *et al.* 2009, p. 6). Agriculture and aquaculture are a minor but locally important contributor to overall loss and degradation of the red knot's nonbreeding habitat, particularly for moderate numbers of red knots that winter or stopover in Northeast Brazil where habitats were likely impacted by the rapid expansion of shrimp farming since 1998 (Carlos *et al.* 2010, entire).

Within the breeding portion of the range, the primary threat to red knot habitat is from climate change. With arctic warming, vegetation conditions on the breeding grounds are changing, which is expected to eventually cause the zone of nesting habitat to shift north and contract (Feng *et al.* 2012, pp. 1359, 1366; Meltofte *et al.* 2007, p. 35; Arctic Climate Impact Assessment (ACIA) 2005, pp. 991, 998). Studies have already documented changes in arctic vegetation (e.g., increases in peak "greenness" and plant biomass; advancing of the arctic tree line; increased shrub abundance, biomass, and cover; increased plant canopy heights; and decreased prevalence of bare ground (Summary for Policymakers in IPCC 2014, p. 32; Chapter 28 in IPCC 2014, p. 12)). Vegetation effects are likely exacerbated by loss of sea ice (Bhatt *et al.* 2010, pp. 1–2l; Meltofte *et al.* 2007, p. 36). Arctic freshwater systems, foraging areas for red knots during the nesting season, are particularly sensitive to climate change and are already being affected (ACIA 2005, p. 1012; Meltofte *et al.* 2007, p. 35). Unpredictable but profound ecosystem changes (e.g., changing interactions among predators, prey, and competitors) are also likely to occur. There are early warning signs that arctic ecosystems are already experiencing irreversible regime shifts (Summary for Policymakers in IPCC 2014, p. 12). We conclude that ecosystem changes in the Arctic are already underway and likely to continue, and that arctic ecosystems likely face much greater future change that may be abrupt and irreversible. Further, climate change is opening the Arctic to development such as oil and gas exploration, commercial shipping, tourism, and fishing (Niles 2013; National Research Council (NRC) 2013, p. 4; Smith and Stephenson 2013, p. 2; Astill 2012; Roach 2007).

FACTOR B: Threats to the red knot from overutilization for commercial, recreational, scientific, or educational purposes exist in parts of the Caribbean and South America. Specifically, legal and illegal hunting do occur. We expect mortality of individual knots from hunting to continue into the future, but at stable or decreasing levels due to the recent international attention to shorebird hunting, and due to new voluntary and regulatory hunting restrictions in some areas.

Legal and illegal sport and market hunting in the mid-Atlantic and Northeast United States substantially reduced red knot populations in the 1800s, and we do not know if the subspecies ever fully recovered its former abundance or distribution (Karpanty *et al.* 2014, p. 2; Cohen *et al.* 2008; Harrington 2001, p. 22). Neither legal nor illegal hunting are currently a threat to red knots in the United States, but both occur in the Caribbean and parts of South America (Harrington 2001, p. 22). Hunting pressure on shorebirds in the Lesser Antilles (e.g., Barbados, Guadeloupe) is very high (USFWS 2011e, pp. 2–3), but only small numbers of red knots have been documented on these islands, so past mortality may not have exceeded tens of birds per year (G. Humbert pers. comm. November 29, 2013). Red knots are no longer being targeted in Barbados or Guadeloupe, and other measures to regulate shorebird hunting on these islands are being negotiated (G. Humbert pers. comm. November 29, 2013; McClain 2013; USFWS 2011e, p. 2). Much larger numbers (thousands) of red knots occur in the Guianas, where legal and illegal subsistence shorebird hunting is common (CSRPN 2013; Niles 2012b; Ottema and Spaans 2008, p. 343). About 20 red knot mortalities have been documented in the Guianas (D. Mizrahi pers. comm. October 16, 2011; Harrington 2001, p. 22), but total red knot hunting mortality in this region cannot be surmised. As of 2013, shorebird hunting was unregulated in French Guiana (A. Levesque pers. comm. January 8, 2013; D. Mizrahi pers. comm. October 16, 2011). However, a ban on hunting all shorebird species has been proposed in French Guiana (CSRPN 2013), and the red knot was designated a protected species in October 2014 (C. Carichiopulo and N. de Pracontal pers. comm. October 10, 2014). Subsistence shorebird hunting was also common in northern Brazil, but has decreased in recent decades (Niles *et al.* 2008, p. 99).

We have no evidence that hunting was a driving factor in red knot population declines in the 2000s, or that hunting pressure is increasing. While only low to moderate red knot mortality is documented, additional undocumented mortality is likely. The findings of Watts (2010, p. 39) suggest that even moderate (hundreds of birds) direct human-caused mortality may begin to have population-level effects on the red knot. We do not have reliable information to reasonably know if hunting mortality is or was previously at this level in the Guianas, though we conclude it was likely much lower (tens of birds) in the Caribbean islands. In contrast, catch limits, handling protocols, and studies on the effects of research activities on survival all indicate that overutilization for scientific purposes is not a threat to the red knot (Niles *et al.* 2010a, p. 124; L. Niles and H. Sitters pers. comm. September 4, 2008; Niles *et al.* 2008, p. 100).

FACTOR C: From our review of best available data, we conclude that disease is not a threat to red knot populations. Predation pressures exacerbate other threats in some nonbreeding areas, but likely contribute little direct mortality. Natural cycles of high predation rates on the breeding grounds are not a threat to red knot populations, but disruption of these cycles from climate change, which may lead to prolonged periods of low productivity, is a threat to the red knot.

Red knots may be adapted to parasite-poor habitats and may, therefore, be susceptible to parasites when migrating or wintering in high-parasite regions (Piersma 1997, p. 623). However, we have no evidence that parasites have affected red knot populations beyond causing normal, background levels of mortality (D'Amico *et al.* 2008, pp. 193, 197; Harrington 2001, p. 21), and we have no indications that parasite infection rates or red knot fitness impacts are likely to increase. Therefore, we conclude that parasites are not a threat to the red knot. For the most prevalent viruses found in shorebirds within the red knot's geographic range (e.g., avian influenza, avian paramyxovirus), infection rates in red knots are low, and health effects are minimal or have not been documented (D. Stallknecht pers. comm. January 25, 2013; Maxted *et al.* 2012, pp. 322–323; Coffee *et al.* 2010, p. 484; Escudero *et al.* 2008, pp. 494–495; Niles *et al.* 2008, p. 101; D'Amico *et al.* 2007, p. 794). Therefore, we conclude that viral infections do not cause significant mortality and are not a threat to the red knot. However, we acknowledge an unlikely but potentially high-impact, synergistic effect among avian influenza, environmental contaminants, and climate change could produce a population-level impact in Delaware Bay.

Outside of the breeding grounds, predation is not directly effecting red knot populations despite some mortality (Niles *et al.* 2008, p. 28). At key stopover sites, however, localized predation pressures exacerbate other threats to red knot populations by pushing red knots out of otherwise suitable foraging and roosting habitats, causing disturbance, and possibly causing changes to stopover duration or other aspects of the migration strategy (Niles 2010a; Watts 2009b; Niles *et al.* 2008, pp. 101, 116; Lank *et al.* 2003, p. 303). In addition, predation pressure may induce sublethal physiological stress that can impact shorebird fitness (Clark and Clark 2002, p. 49). We expect the direct and indirect effects of predators to continue at the same level or decrease slightly over the next few decades.

Within the breeding range, normal 3- to 4-year cycles of high predation, mediated by rodent (e.g., lemming) cycles, result in years with extremely low reproductive output but do not threaten the survival of the red knot at the subspecies level (Niles *et al.* 2008, pp. 64, 101; Meltofte *et al.* 2007, p. 20). It is believed shorebirds, such as red knots, have adapted to these cycles, therefore these natural cycles are not considered a threat to the red knot. What is a threat, however, is that these natural rodent/predator cycles are being disrupted by climate change, which may increase predation rates on shorebirds over the long term and have subspecies-level effects (Chapter 28 in IPCC 2014, p. 14; Fraser *et al.* 2013, pp. 13, 16; Brommer *et al*. 2010, p. 577; Ims *et al.* 2008, p. 79; Kausrud *et al.* 2008, p. 98). Disruptions in the rodent-predator cycle pose a substantial threat to the red knot, as they may result in prolonged periods of very low reproductive output (Meltofte *et al.* 2007, p. 22). Such disruptions have already occurred and may increase due to climate change (Chapter 28 in IPCC 2014, p. 14; Fraser *et al.* 2013, pp. 13, 16; Brommer *et al*. 2010, p. 577; Ims *et al.* 2008, p. 79; Kausrud *et al.* 2008, p. 98). The substantial impacts of elevated egg and chick predation on shorebird reproduction are well known (Smith and Wilson 2010, pp. 615, 621; Meltofte *et al.* 2007, p. 20), although the red knot's capacity to adapt to long-term changes in predation pressure is unknown (Meltofte *et al.*

2007, p. 34). The threat of persistent increases in predation in the Arctic may already be having subspecies-level effects (Fraser *et al.* 2013, p. 13) and is anticipated to increase into the future. Further, warming temperatures and changing vegetative conditions in the Arctic are likely to bring additional changes in the predation pressures faced by red knots, such as colonization by new predators from the south, though we cannot forecast how such ecosystem changes are likely to unfold.

FACTOR D: We have reviewed the adequacy of existing regulatory mechanism across the range of the red knot. In Canada, the Species at Risk Act provides protections for the red knot and its habitat, both on and off of Federal lands. The red knot is afforded additional protections under Canada's Migratory Birds Convention Act and by provincial law in four of the Provinces. Red knots are legally protected from direct take and hunting in several Caribbean and Latin American countries, but we lack information regarding the implementation or effectiveness of these measures. For many other countries, red knot hunting is unregulated, or we lack sufficient information to determine if red knot hunting is legal. We also lack information for countries outside the United States regarding the protection or management of red knot habitat, and regarding the regulation of other activities that threaten the red knot such as development, disturbance, oil spills, environmental contaminants, and wind energy development.

In the United States, the Migratory Bird Treaty Act, even with recent changes in interpretation, and state wildlife laws protect the red knot from direct take resulting from scientific study and hunting. The Sikes Act, the National Park Service Organic Act, and the National Wildlife Refuge System Improvement Act provide protection for the red knot from habitat loss and inappropriate management on Federal lands. Section 404 of the Clean Water Act, the Rivers and Harbors Act, the Coastal Barrier Resources Act, the Coastal Zone Management Act, and State mechanisms regulate shoreline stabilization and development. State and local regulations provide varying levels of protection from impacts associated with beach grooming. Several Federal and State policies are in effect to stem the introductions and effects of invasive species, but collectively do not provide complete protection to the red knot from impacts to its habitats or food supplies resulting from beach or marine invaders or the spread of harmful algal species. Although threats to the horseshoe crab egg food resource remain, regulatory management of the horseshoe crab fishery under the Adaptive Resource Management (ARM) framework is adequate to address threats to the knot's Delaware Bay food supply from direct harvest. Regarding climate change, the U.S. Environmental Protection Agency (USEPA) has developed several initiatives related to greenhouse gasses (GHGs). However, some of the USEPA's proposed GHG regulations are not yet final and, even when final, substantially greater reductions in GHGs would still be needed at multiple scales to reduce the magnitude of likely climate changes over the next several decades. Although we lack information regarding the overall effect of recreation management policies on the red knot, we are aware of a few locations in which beaches are closed, regulated, or monitored to protect nonbreeding shorebirds. Relatively strong Federal laws likely reduce risks to red knots from oil spills, but cannot fully abate the risk of oil spills and leaks. Similarly, Federal law and policy reduce the red knot's collision risks from new wind turbine development, but some level of mortality is expected upon buildout of the Nation's wind energy infrastructure.

FACTOR E: Based on our review of the best available scientific and commercial data, the red knot faces subspecies-level impacts from other natural and manmade factors that are already occurring and are anticipated to continue and possibly increase into the future.

Reduced food availability at the Delaware Bay stopover site due to commercial harvest of the horseshoe crab is considered a primary causal factor in the decline of rufa red knot populations in the 2000s (Escudero *et al.* 2012, p. 362; McGowan *et al.* 2011a, pp. 12–14; Niles *et al.* 2008, pp. 1–2; Baker *et al.* 2004, p. 875). Under the current management framework (the ARM), the present horseshoe crab harvest is not considered a threat to the red knot. However, continued implementation of the ARM is imperiled by lack of funding to support the requisite monitoring programs. With or without the ARM, it is not yet known if the horseshoe crab egg resource will continue to adequately support red knot population growth over the next decade. Notwithstanding the importance of the horseshoe crab and Delaware Bay, the red knot faces a range of ongoing and emerging threats to its food resources throughout its range, including small prey sizes from unknown causes (Escudero *et al.* 2012, pp. 359–362; Espoz *et al.* 2008, pp. 69, 74), warming water and air temperatures (Jones *et al.* 2010, pp. 2255–2256), ocean acidification (International Geosphere-Biosphere Programme (IGBP) *et al.* 2013, pp. 9, 16; NRC 2010b, pp. 68–69), physical habitat changes (Chapter 5 in IPCC 2014, p. 21; Rehfisch and Crick 2003, p. 88; Najjar *et al.* 2000, p. 225), possibly increased prevalence of disease and parasites (Ward and Lafferty 2004, p. 543), marine invasive species (Seebens *et al.* 2013, p. 782; Ruesink *et al.* 2005, pp. 671–674; Grosholz 2002, p. 22–23), and burial and crushing of invertebrate prey from sand placement and recreational activities (Sheppard *et al.* 2009, p. 113; Schlacher *et al.* 2008b, pp. 345, 348; Schlacher *et al.* 2008c, pp. 878, 882; Greene 2002, p. 24).

In addition, the red knot's life-history strategy makes this species inherently vulnerable to mismatches in timing between its annual cycle and those periods of optimal food and weather conditions upon which it depends (Galbraith *et al.* 2014, p. 7 and Supplement 1; Liebezeit *et al.* 2014, p. 2; Conklin *et al.* 2010, p. 4; Gill *et al.* 2013, p. 1; Hurlbert and Liang 2012, pp. 4–5; McGowan *et al.* 2011a, pp. 2, 16; Smith *et al.* 2011a, p. 575; Meltofte *et al.* 2007, p. 36). The red knot's sensitivity to timing asynchronies has been demonstrated through a population-level response, as the late arrivals of birds in Delaware Bay is generally accepted as a key causative factor (along with reduced supplies of horseshoe crab eggs) behind population declines in the 2000s (Baker *et al.* 2004, p. 878). The factors that caused delays in the spring migrations of red knots from Argentina and Chile are still unknown (Niles *et al.* 2008, p. 2), and we have no information to indicate if this delay will reverse, persist, or intensify in the future. Superimposed on the existing threat of late arrivals in Delaware Bay are new threats emerging due to climate change (Summary for Policymakers in IPCC 2014, p. 30; Root *et al.* 2013, pp. 85–88; Hurlbert and Liang 2012, p. 4), such as changes in the timing of reproduction for both horseshoe crabs and mollusks (Burrows *et al.* 2011, p. 652; Poloczanska *et al.* 2013, pp. 3–4; Smith *et al.* 2010b, p. 563; van Gils *et al.* 2005a, p. 2615; van Gils *et al.* 2005b, pp. 126–127; Philippart *et al.* 2003, p. 2171). Climate change may also cause shifts in the period of optimal arctic insect and snow conditions relative to the time period when red knots currently breed (Grabowski *et al.* 2013, p. 1097; McGowan *et al.* 2011a, p. 13; Smith *et al.* 2010a, p. 292; Tulp and Schekkerman 2008, p. 48; Meltofte *et al.* 2007, pp. 7, 25; Piersma *et al.* 2005, p. 270; Schekkerman *et al.* 2003, p. 340). The red knot's adaptive capacity to deal with numerous changes in the timing of resource availability across its geographic range is largely unknown (Liebezeit *et al.* 2014, pp. 1, 10;

Grabowski *et al.* 2013, p. 1103; Meltofte *et al.* 2007, p. 34). A few examples suggest some flexibility in red knot migration strategies (D. Newstead pers. comm. May 8, 2014; Grabowski *et al.* 2013, pp. 1097, 1100–1103; Smith *et al.* 2010a, p. 292; González *et al.* 2006, p. 115; González *et al.* in International Wader Study Group (IWSG) 2003, p. 18), but differences between the annual timing cues of red knots (at least partly celestial and endogenous) (Liebezeit *et al.* 2014, p. 10; Conklin *et al.* 2010, p. 5; Gill *et al.* 2013, p. 1; McGowan *et al.* 2011a, p. 16; Cadée *et al.* 1996, p. 82) and their prey (primarily environmental) (Smith *et al.* 2010b, p. 563; Philippart *et al.* 2003, p. 2171) suggest there are limitations on the adaptive capacity of red knots to cope with increasing frequency or severity of asynchronies.

Other factors are likely to exacerbate the effects of reduced prey availability and asynchronies, including human disturbance (Burger and Niles 2013a, p. 23; Burger and Niles 2013b, p. 657; Escudero *et al.* 2012, pp. 358, 362), competition with gulls (Niles *et al.* 2008, p. 107; Burger *et al.* 2007, p. 1162), and behavioral changes from wind energy development (Kuvlesky *et al.* 2007, p. 2489). Additional factors are likely to increase the levels of direct red knot mortality, such as harmful algal blooms (HABs) (Newstead 2014a, p. 23; Anderson 2007, p. 2), oil spills (Anderson *et al.* 2012, p. 10; WHSRN 2012; Kalasz 2008, pp. 39–40; Niles *et al.* 2008, p. 98, 100), and collisions with wind turbines (D. Newstead pers. comm. March 5, 2013; Burger *et al.* 2012c, p. 370; Burger *et al.* 2011, p. 348; Watts 2010, p. 1; Kuvlesky *et al.* 2007, p. 2487). In addition to elevating background mortality rates, these three factors pose the potential for a low-probability but high-impact event if a severe HAB or major oil spill occurs when and where large numbers of red knots are present, or if a mass-collision event occurs at wind turbines during migration.

CUMULATIVE EFFECTS AND CONCLUSION: Red knots face a wide range of threats across their range on multiple geographic and temporal scales. The effects of some smaller threats may act in an additive fashion to ultimately impact populations or the subspecies as a whole (cumulative effects). Other threats may interact synergistically to increase or decrease the effects of each threat relative to the effects of each threat considered independently (synergistic effects). For example, reduced food availability has been shown to interact synergistically with asynchronies and several other threats, such as disturbance, predation pressure, and competition with gulls (Escudero *et al.* 2012, p. 362; Dey *et al.* 2011a, pp. 7, 9; Breese 2010, p. 3; Niles *et al.* 2008, p. 2; Atkinson *et al.* 2007, p. 892; Niles *et al.* 2005, p. 4; Baker *et al.* 2004, p. 878). We conclude that a number of threats are likely contributing to habitat loss, anthropogenic mortality, or both, and thus contribute to the red knot's threatened status, particularly considering the cumulative and synergistic effects of these threats, and that several key populations of this species have already undergone considerable declines.

APPENDIX B.
Updated Population Information from the Argentina/Chile Wintering Region and the Delaware Bay Spring Staging Area

Table C1. Aerial counts and modeled population size estimates of red knots in Argentina and Chile, winters 1982 to 2018

Year	Tierra del Fuego* Aerial Count	Patagonia* Aerial Count	Total Aerial Count	Modeled Estimate Tierra del Fuego and Patagonia
1982		14,314[a]		
1985	53,232[a]			
1995				74,193[b]
2000	51,255[c]			
2001	29,745[c]**			32,623[b]
2002	27,242[c]	2,029[c]	29,271[c]	34,140[b]
2003	29,915[c]	560[c]	30,475[c]	28,966[b]
2004	30,778[d]	880[d]	31,658[d]	
2005	17,653[e]			
2006	17,211[e]			
2007	17,360[e]			
2008	14,800[e]			
2009	17,780[e]			
2010	16,260[e]			
2011	9,850[e]			
2012	14,200[d]	574[d]	14,774[d]	
2013	10,105[e]			
2014	14,200[e]			
2015	12,780[e]			
2016	11,150[f]			
2017	13,127[f]			
2018	9,840[g]			

Table 5 footnotes and sources:

*See Figure 4 in the supplemental listing document (USFWS 2014) for a map.

**Only the single largest wintering area (Bahía Lomas) and one small adjacent site were surveyed on Tierra del Fuego in 2001.

(a) Morrison, R.I.G., and R.K. Ross. 1989. Atlas of Nearctic shorebirds on the coast of South America in two volumes. Canadian Wildlife Service, Ottawa, Canada.

(b) González, P.M., M. Carbajal, R.I.G. Morrison, and A.J. Baker. 2004. Tendencias poblacionales del playero rojizo (*Calidris canutus rufa*) en el sur de Sudamérica. Ornitología Neotropical 15(Suppl.):357-365.

(c) Morrison, R.I.G., K. Ross, and L.J. Niles. 2004. Declines in wintering populations of red knots in southern South America. The Condor 106:60-70.

(d) Morrison, G. 2014. Scientist Emeritus. Email of February 18, 2014. Shorebirds, Environment Canada, National Wildlife Research Centre, Carleton University. Ottawa, Ontario.

(e) Dey, A.D., L.J. Niles, J.A.M. Smith, H.P. Sitters, R.I.G. Morrison, D. Mizrahi, B. Watts, T. Baxter. 2015. Update to the status of the red knot (*Calidris canutus rufa*) in the Western Hemisphere. Draft unpublished report of the New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program, Trenton, New Jersey. 15 pp.

(f) Western Hemisphere Shorebird Reserve Network. 2017. Promising News of the Red Knot Wintering Population. August 21, 2017 press release. https://www.whsrn.org/red-knot-news [Accessed March 13, 2018].

(g) Western Hemisphere Shorebird Reserve Network. 2018. Red Knot Population in Tierra del Fuego Crashes to a New Low. February 26, 2018 press release. https://www.whsrn.org/red-knot-low [Accessed March 13, 2018].

Figure B1. Red Knot Numbers and Trend in the Argentina/Chile Wintering Region

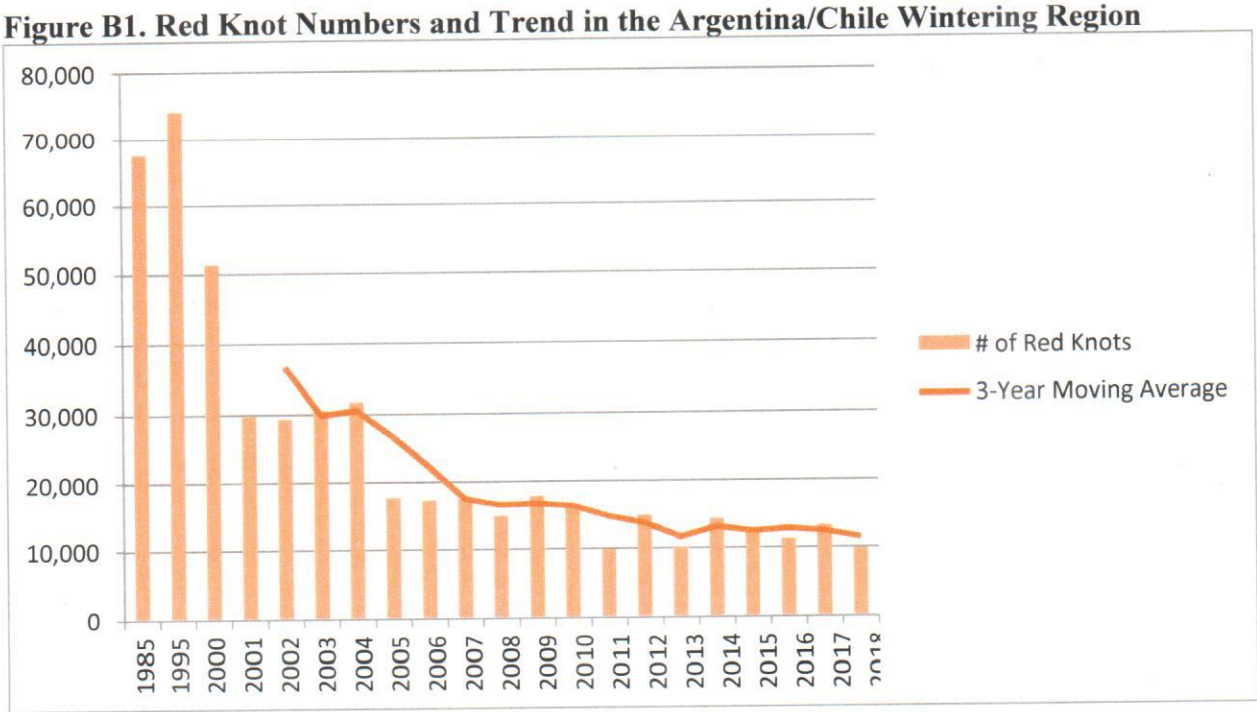

Table C2. Peak counts of red knots in Delaware Bay from aerial and ground surveys, and modeled estimates of the bay's total stopover population, spring 1981 to 2017

Year	Peak* Count	Modeled Estimates of Total Stopover Population*	Range in Modeled Estimates
1981	67,450(a)**		
1982	95,530(b)		
1983	16,859(c)		
1986	58,156(d)		
1987	38,790(d)		
1988	34,750(d)		
1989	95,490(d)	152,900(e)	±50,300 Standard Deviation(e)
1990	45,860(d)		
1991	27,280(d)		
1992	25,595(d)		
1993	44,000(d)		
1994	52,055(d)		
1995	38,600(d)		
1996	19,445(d)		
1997	41,855(d)		
1998	50,360(d)	77,000(f)	28,000-126,000 95% Confidence Interval(f)
1999	49,805(d)	77,000(f)	28,000-126,000 95% Confidence Interval(f)
2000	43,145(d)	77,000(f)	28,000-126,000 95% Confidence Interval(f)
2001	36,125(d)	77,000(f)	28,000-126,000 95% Confidence Interval(f)
2002	31,695(d)		
2003	16,255(d)		
2004	13,315(d)	17,108(g)	14,515-19,701 95% Confidence Interval(g)
2004	13,315(d)	17,707(h)	12,800-22,614 95% Confidence Interval(h)
2005	15,345(d)		
2006	13,445(d)	19,555(g)	17,927-21,184 95% Confidence Interval(g)
2007	12,375(d)		
2008	15,395(d)		
2009	24,000(i)***		
2010	14,475(i)		
2011	12,804(i)	43,570(j)	40,880-46,570 95% Confidence Interval(j)
2012	25,458(i)***	44,100(j)	41,860-46,790 95% Confidence Interval(j)
2013	25,596(i)***	48,955(j)	39,119-63,130 95% Confidence Interval(j)
2014	24,980(j)	44,010(j)	41,900–46,310 95% Confidence Interval(j)
2015	24,890(j)	60,727(j)	55,568–68,732 95% Confidence Interval(j)
2016	21,128(j)	47,254(j)	44,873–50,574 95% Confidence Interval(j)
2017	17,969(j)	49,405(j)	46,368–53,109 95% Confidence Interval(j)

Table 6 footnotes and sources:

*Because birds pass in and out of a stopover area, the one-day peak count for a particular year is lower than the total (season-long) stopover population (also called the passage population). Using resightings of marked birds, several attempts have been made to estimate the total stopover population of Delaware Bay through mathematical modeling, which should not be confused with the peak counts. See USFWS (2014) for more on methodologies.

**Only New Jersey was surveyed in 1981. For reference, the total numbers of red knots in Delaware Bay was relatively evenly distributed between New Jersey and Delaware from 1986 to 1992, suggesting that the true peak count for the bay could have been roughly double the number recorded in 1981.

***Data from 2009, 2012, and 2013 are from ground counts, while all other years are from aerial counts. Peak counts in 2009 and 2012 were adjusted down by survey sponsors based on methodological concerns.

(a) Wander, W., and P. Dunne. 1982. Species and numbers of shorebirds on the Delaware bayshore of New Jersey - spring 1981, Occasional Paper Number 140. Records of N.J. Birds 7(4):59-64.

(b) Dunne, P., D. Sibley, C. Sutton, and W. Wander. 1982. 1982 aerial shorebird survey of the Delaware Bay endangered species. New Jersey Birds 9:68-74.

(c) Kochenberger, R. 1983. Survey of shorebird concentrations along the Delaware bayshore. Peregrine Observer spring 1983. New Jersey Audubon Publications.

(d) Clark, K.E., R.R. Porter, and J.D. Dowdell. 2009. The shorebird migration in Delaware Bay New Jersey Birds 35(4):85-92.

(e) Harrington, B.A. 2001. Red knot (*Calidris canutus*). *In* A. Poole, and F. Gill, eds. The birds of North America, No. 563, The Birds of North America, Inc., Philadelphia, Pennsylvania.

(f) Atkinson, P.W., I.G. Henderson, and N.A. Clark. 2002. A preliminary analysis of the survival rates of red knots *Calidris canutus rufa* passing through the State of Delaware 1997-2001. British Trust for Ornithology, Norfolk, UK.

(g) Cohen, J.B., S.M. Karpanty, J.D. Fraser, B.D. Watts, and B.R. Truitt. 2009. Residence probability and population size of red knots during spring stopover in the mid-Atlantic region of the United States. Journal of Wildlife Management 73(6):939-945.

(h) Gillings, S., P.W. Atkinson, A.J. Baker, K.A. Bennett, N.A. Clark, K.B. Cole, P.M. González, K.S. Kalasz, C.D.T. Minton, N.J. Niles, and et al. 2009. Staging behaviour in red knot (*Calidris canutus*) in Delaware Bay: Implications for monitoring mass and population size. The Auk 126:54-63.

(i) Dey, A.D., L.J. Niles, H.P. Sitters, K. Kalasz, R.I.G. Morrison, T.R. Danihel, and T.R. Catania. 2014. Update to the status of the red knot *Calidris canutus rufa* in the Western Hemisphere. Draft report to the ASMFC. Unpublished report to the New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program, Trenton, New Jersey. 5 pp.

(j) Lyons, J. 2017. Memo to the Delaware Bay ARM Working Group. Red Knot Stopover Population Estimate for 2017. USGS Patuxent Wildlife Research Center, Laurel, Maryland.

Figure B2. Red Knot Numbers and Trend in the Delaware Bay Spring Staging Area